Quick Manual for the AXAF Guide and Acquisition Star Catalog AGASC1.1

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6 Nov, 1996

OVERVIEW

1. DELIVERY FORMAT (CDROM)

2. FITS FORMAT and SUMMARY OF ENTRIES

3. STAR COUNTS

4. FUTURE RELEASES

1 CDROM FORMAT

AGASC1.1 (2.2Gb) spans 4 CDROMs (660Mb capacity each).

Directory structure analogous to the original HST GSC.

The top directory of each CDROM includes these files:

```
-------------------------------------------------------------
  README.TXT   - Introduction.  ASCII
  AGASC        - Directory for AGASC region files.      FITS
  TABLES       - Directory for AGASC supporting tables. FITS
-------------------------------------------------------------
```

In the tables subdirectory should are these tables:

```
-------------------------------------------------
  COMMENTS.TXT - Introduction and general comments.  ASCII
  REGIONS      - Boundaries of GSC regions.  FITS binary table
  LG_REG_X     - Index to large regions.  FITS binary table
  SM_REG_X     - Index to small regions.  FITS binary table
-------------------------------------------------
```

Directory AGASC contains subdirectories for 7.5degree large zones in declination; these subdirectories in turn contain the GSC region files in FITS format for the respective zone, with file identifiers of the form NNNN.fits

The AGASC consists of about 10,000 regions tables with a few thousand objects each. These are in FITS binary table (BINTABLE) format.

2 FITS FORMAT for the AGASC1.1

3 parts: the primary header, the table header, and the table data. The conventions for FITS Binary Tables are detailed in
http://fits.nrao.edu/FITS.html

Below is a summary of bytes in a typical FITS regions table.

Section	No. of recs	bytes per rec	bytes	No. of 2880 byte recs
primary header				
hdr kywds	29	80	2320	
end kywd	1	80	80	
padding to 2880			480	1
table header				
hdr keywords	161	80	12880	
end kywd	1	80	80	
padding to 2880			1440	5
table data				
data	2391	104	248664	
padding to 2880			1896	87
total				93

The length of the header information will be the same for all the regions files in the AGASC1.1. That length is 6×2880= 17280bytes. Therefore, once 17280bytes have been read, star data follows.

The data for each star will always amount to 104 bytes in the AGASC1.1 The FITS format data types and bit-lengths used for each data item for each star are as follows:

fmt	bits	used	totbits
A	8	0	0
B	8	6	48
I	16	19	304
J	32	6	192
E	32	5	160
D	64	2	128
			832bits = 104 bytes per star

3 SUMMARY of ENTRIES

104 bytes represent 38 different data items. Dummy values are recorded for all data items as –9999.

DATUM	TYPE	explanation (units)
AGASC_ID	1J	unique AGASC1.1 ID number
RA	1D	right ascension (equinox 2000.0, decimal degrees)
DEC	1D	declination (equinox 2000.0, decimal degrees)
POS_ERR	1I	total position error (milli-arcsec)
POS_CATID	1B	source for RA and DEC
EPOCH	1E	Date of position measurement (Julian years)
PM_RA	1I	proper motion in r.a (milli-arcsec per year)
PM_DEC	1I	proper motion in dec (milli-arcsec per year)
PM_CATID	1B	source for PM
MAG_ACA	1E	calculated mag in AXAF ACA bandpass (mag)
MAG_ACA_ERR	1I	error in MAG_ACA (.01 mag)
CLASS	1I	morphological code ala GSC
MAG	1E	original mag as listed (mag)
MAG_ERR	1I	error in MAG (.01 mag)
MAG_BAND	1I	bandpass code of MAG
MAG_CATID	1B	source for MAG
COLOR1	1E	cataloged or estimated B-V color, used for MAG_ACA (mag)
COLOR1_ERR	1I	error in COLOR1 (.01 mag)
C1_CATID	1B	source for COLOR1
COLOR2	1E	other cataloged color as listed (mag)
COLOR2_ERR	1I	error in COLOR2 (0.1 mag)
C2_CATID	1B	source for COLOR2)
VAR	1I	variability flag
VAR_CATID	1B	source for VAR
ASPQ1	1I	Spoiler Quality code for Aspect Stars, 1
ASPQ2	1I	Spoiler Quality code for Aspect Stars, 2
ASPQ3	1I	Spoiler Quality code for Aspect Stars, 3
ACQQ1	1I	Spoiler Quality code for Acquisition Stars, 1 (.01 mag)
ACQQ2	1I	Spoiler Quality code for Acquisition Stars, 2 (.01 mag)
ACQQ3	1I	Spoiler Quality code for Acquisition Stars, 3 (.01 mag)
ACQQ4	1I	Spoiler Quality code for Acquisition Stars, 4 (.01 mag)
ACQQ5	1I	Spoiler Quality code for Acquisition Stars, 5 (.01 mag)
ACQQ6	1I	Spoiler Quality code for Acquisition Stars, 6 (.01 mag)
XREF_ID1	1J	Star ID number from catalog 1 (GSC1.1)
XREF_ID2	1J	Star ID number from catalog 2 (PPM)
XREF_ID3	1J	Star ID number from catalog 3 (TOC)
XREF_ID4	1J	Star ID number from catalog 4 (undetermined)
XREF_ID5	1J	Star ID number from catalog 5 (undetermined)

4 STAR COUNTS in AGASC1.1

The surface density of objects brighter than $m_{ACA} = 10.2$ (G0V zeropoint) after both positional and mag matching of the HST GSC1.1 to the PPM catalog is as low as 4.7deg^{-2} at $|b| > 80°$.

Matching only PPM stars to the GSC1.1 *does not* achieve the required FOM surface density of 5.11deg^{-2} to an instrumental magnitude of $m_{ACA} = 10.2$.

Galactic models/data suggest a total surface density of 7.6 stars deg^{-2} to $V = 10.5$, even at the NGP. The PPM is severely incomplete for $V > 10$. The required FOM may be reached if other catalogs can be included.

To avoid red spoilers fainter than $V = 10.5$, the AGASC should be as complete as possible, with colors, to $V \approx 14$.

This corresponds quite well to the HST GSC1.1, which, however lacks color and proper motion information - the motivation for this catalog merging.

5 FUTURE RELEASES of AGASC

A variety of catalogs are being considered for inclusion to make future versions better satisfy our requirements.

———————- AGASC1.2: (due 9/97) ———————

Merge of the Tycho Output Catalog (TOC) with the HST GSC.

The TOC (release date Spring 1997) includes about a million stars 'almost complete' to V=10.5 with typical precision 0.04 mag, colors with $(B-V)$ precision < 0.06 mag, and astrometry with precision < 0.01 arcsec. Tycho stars are already cross-referenced to GSC IDs for easy matching.

——————— AGASC2.0: (due 9/99) ———————

This version should include accurate mags, colors and astrometry for all objects down to at least $V = 14.5$. We expect this to include either the scanned POSSII or the Flagstaff USNO survey, both of which are now underway.

USNO-A 1.0 contains about 488 million objects, complete to at least $B \sim 19$, with photometric accuracy < 0.40 mag, and astrometric accuracy < 0.25 arcsec.

USNO-A 2.0 (scheduled release October 1997) will tie-in all astrometry to Tycho/Hipparcos system. AGASC2.0 may well be ready before the due date.

AGASC2.x:

The ACA magnitudes listed in future versions of the catalog may also be modified several ways.

1) Based on observed in-flight ACA magnitudes, a more accurate magnitude calculation as a function of (B–V) color can be verified, and if necessary, a recalibration of the whole catalog may be performed.

2) Observed ACA magnitudes will be stored and substituted into a working version of the AGASC, with occasional re-release versions planned.

AXAF Science Center

Harvard–Smithsonian Center for Astrophysics

MEMORANDUM

November 5, 1996

To: AXAF Mission Planning and Scheduling Working Group

From: Paul Green

Subject: Quick Manual for AXAF Guide and Acquisition Star Catalog, AGASC1.1

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1 The AXAF GUIDE and AQUISITION STAR CATALOG (AGASC)

The primary objective of the AXAF Aspect Camera Assembly (ACA) is to measure the image positions of selected target stars and fiducial lights in its field of view (FOV). The AXAF-I on board computer uses gyro attitude data and ACA image centroids for real-time pointing. Post-facto aspect determination is required for observations over 100 sec to compensate for the apparent motion of the X-ray image on the SI focal plane. When a maneuver is completed, at least 2 acquisition stars must be acquired before acquiring guide stars and fiducial lights. Up to 8 images can be tracked, including the fid lights. The ground provides expected positions in the ACA FOV for these objects, using the AGASC. At least 5 stars brighter than m=10.2 in the ACA instrumental mag (m_{ACA}) system should be provided from ground 95% of the time, anywhere on the sky, for the predicted end of life (EOL) FOV of 1.79 square degrees. To enable an astrometric net of sufficient density, the current best starting point is the Hubble Space Telescope (HST) Guide Star Catalog (GSC), described below (§ 5.1). The depth of the GSC is adequate to meet AXAF requirements even for the reddest stars (see § 9) and includes many stars too faint for the Star Selection Algorithm (SSA) that may nevertheless complicate the optimal selection of stars ('spoilers'). However, to predict the ACA mag in advance, colors for each star are required. Proper motions (p.m.) are also advisable, since high p.m. stars could move significantly over the extended lifetime of the AXAF mission. Currently, the largest consistent published catalog providing colors and proper motions is the Positions and Proper Motions (PPM) Catalog (see § 5.2 below).

AGASC1.1 is the merge of these two catalogs, the HST GSC1.1 and the PPM. The merged catalog will include information for unmatched stars, and the best information for matched stars.

2 CDROM FORMAT

The AXAF Guide and Acquisition Star Catalog (AGASC) was originally created in SYBASE and is also presented in FITS (Flexible Image Transport System) files, and may be distributed in a variety of formats, including CD-ROMs (compact disc, read only memory; see § 2). This issue, Version 1.1, corresponds to the AGASC as created 28 August 1996.

Since CDROMs only hold 660Mb, the AGASC1.1 (2.2Gb) spans 4 CDROMs. CDROMs will probably be considered a 'transport medium', and the original directories will be reconstructed from the CDROM, or else soft links can be used.

The AGASC1.1 CDROMs will be ISO9660 Compliant with Rock-Ridge Extensions, and

therefore readable on all HEAD/SUN CDROM readers. The directory structure is analogous to the original HST GSC disk structure, except for division into 4 CDROMs, as described below. FITS files will be organized in a tree under one root directory for each CDROM. An introductory file (readme.txt) and the supporting tables are duplicated on all discs. All data files (with the exception of the file readme.txt and the directory files) are in FITS table format.

The top directory of each CDROM includes the files

```
-------------------------------------------------------------
  README.TXT    - Introduction. ASCII
  AGASC         - Directory for AGASC region files.
  TABLES        - Directory for AGASC supporting tables.
-------------------------------------------------------------
```

In the tables subdirectory should be these tables:

```
-----------------------------------------------
  COMMENTS.TXT  - Introduction and general comments. ASCII
  REGIONS       - Boundaries of GSC regions. FITS binary table
  LG_REG_X      - Index to large regions. FITS binary table
  SM_REG_X      - Index to small regions. FITS binary table
-----------------------------------------------
```

Directory AGASC contains directories for the 7.5 degree zones in declination; these directories in turn contain the GSC region files in FITS format for the respective zone, with file identifiers of the form nnnn.fits, where nnnn is the 4-digit decimal region number, with leading zeroes used as required to fill the field.

The 4 CDROMs host large regions as subdirectories of agasc/. Each large region subdirectory contains a variable number of regions files, whose contents (§ 4) and format (§ 3) are described herein. These subdirectories are shown below with their associated CDROM labeled. This scheme splits the sky at dec=0 and at +/-37.5 degrees

DIR agasc1/	SIZE	DIR agasc2/	SIZE	DIR agasc3/	SIZE	DIR agasc4/	SIZE
n0000/	136328	n3730/	115616	s0000/	120977	s3730/	121641
n0730/	125039	n4500/	102759	s0730/	120310	s4500/	116904
n1500/	121125	n5230/	80599	s1500/	124743	s5230/	97192
n2230/	124394	n6000/	60274	s2230/	127187	s6000/	78812
n3000/	120768	n6730/	44304	s3000/	121920	s6730/	56160
		n7500/	30536			s7500/	32976
		n8230/	8847			s8230/	11009

The AGASC consists of about 10,000 regions tables containing about 2,000 objects each. These will remain in FITS BINTABLE format, with the directory structure in FITS TABLE format.

The data content of the 4 CDROMs amounts to:

AGASC1.1 CDROM	DATA (bytes)
1	627654
2	442935
3	615137
4	514694

3 FITS FORMAT for the AGASC1.1

The star catalog is divided into regions, each having a couple thousand stars in it. Each FITS regions table in the AGASC1.1 consists of 3 parts, the primary header, the table header, and the table data. The conventions for FITS Binary Tables are detailed in Cotton, Tody and Pence (1995, A&A, 113, 159), or at http://fits.nrao.edu/FITS.html

The names of the files are given by the FITS EXTNAME keyword. The primary header array basically just tells FITS software that this FITS file contains a binary table. The table header contains FITS standard descriptions of data format to follow. The table data array contains data for individual stars.

All header records are 80 bytes each. END is always the last keyword in a header. In the FITS standard, each of these 3 main arrays must contain an integer number of 2880byte

records. Therefore, if the number of header or data records do not result in such a number, padding is added.

Below is a summary of bytes in a typical FITS regions table.

Section	No. of recs	bytes per rec	bytes	No. of 2880 byte recs
primary header				
hdr kywds	29	80	2320	
end kywd	1	80	80	
padding to 2880			480	1
table header				
hdr keywords	161	80	12880	
end kywd	1	80	80	
padding to 2880			1440	5
table data				
data	2391	104	248664	
padding to 2880			1896	87
total				93

The total size of the FITS file is 267840 bytes, which corresponds in this case to 93 records of 2880 bytes each. This will change for files that have a different number of stars in them.

NOTE: The length of the header information will be the same for all the regions files in the AGASC1.1. That length is $6 \times 2880 =$ 17280bytes. Therefore, once 17280bytes have been read, star data follows.

The data for each star will always amount to 104 bytes in the AGASC1.1 The FITS format data types and bit-lengths used for each data item for each star are as follows:

```
fmt     bits    used    totbits
---------------------------------
A        8      0         0
B        8      6        48
I       16      19      304
J       32      6       192
E       32      5       160
D       64      2       128
---------------------------------
                        832bits = 104 bytes per star
```

We thus use 104 bytes to represent 38 different data items. The data items, their meaning, their units and dataypes are very briefly presented below:

```
DATUM           /explanation (units)
-----------------------------------------------
AGASC_ID        /unique AGASC1.1 ID number
RA              /right ascension (equinox 2000.0, decimal degrees)
DEC             /declination (equinox 2000.0, decimal degrees)
POS_ERR         /total position error (milli-arcsec)
POS_CATID       /source for RA and DEC
EPOCH           /Date of position measurement (Julian years)
PM_RA           /proper motion in r.a (milli-arcsec per year)
PM_DEC          /proper motion in dec (milli-arcsec per year)
PM_CATID        /source for PM
MAG_ACA         /calculated mag in AXAF ACA bandpass (mag)
MAG_ACA_ERR     /error in MAG_ACA (.01 mag)
CLASS           /morphological code ala GSC
MAG             /original mag as listed (mag)
MAG_ERR         /error in MAG (.01 mag)
MAG_BAND        /bandpass code of MAG
MAG_CATID       /source for MAG
COLOR1          /cataloged or estimated B-V color, used for MAG_ACA   (mag)
COLOR1_ERR      /error in COLOR1 (.01 mag)
C1_CATID        /source for COLOR1
COLOR2          /other cataloged color as listed   (mag)
COLOR2_ERR      /error in COLOR2 (0.1 mag)
C2_CATID        /source for COLOR2)
VAR             /variability flag
VAR_CATID       /source for VAR
```

```
ASPQ1           /Spoiler Quality code for Aspect Stars, 1
ASPQ2           /Spoiler Quality code for Aspect Stars, 2
ASPQ3           /Spoiler Quality code for Aspect Stars, 3
ACQQ1           /Spoiler Quality code for Acquisition Stars, 1  (.01 mag)
ACQQ2           /Spoiler Quality code for Acquisition Stars, 2  (.01 mag)
ACQQ3           /Spoiler Quality code for Acquisition Stars, 3  (.01 mag)
ACQQ4           /Spoiler Quality code for Acquisition Stars, 4  (.01 mag)
ACQQ5           /Spoiler Quality code for Acquisition Stars, 5  (.01 mag)
ACQQ6           /Spoiler Quality code for Acquisition Stars, 6  (.01 mag)
XREF_ID1        /Star ID number from catalog 1 (GSC1.1)
XREF_ID2        /Star ID number from catalog 2 (PPM)
XREF_ID3        /Star ID number from catalog 3 (TOC)
XREF_ID4        /Star ID number from catalog 4 (undetermined)
XREF_ID5        /Star ID number from catalog 5 (undetermined)
```

Note that dummy values are recorded for all data items as -9999.

4 EXPLANATION of SELECTED ENTRIES in the AGASC1.1

Stars from other catalogs that were not matched to the original GSC1.1 will be included within the appropriate regions table. Cross-references to the original star ID numbers XREF_IDx are included from the original x=1-5 catalogs we may eventually match.

POSITIONS & EPOCHS: Units are decimal degrees for both RA and DEC, and equinox is always J2000. Proper motions are used to update positions to epoch J2000 whenever possible. The EPOCH is thus listed as 2000.0 for stars with p.m.-updated coordinates, and otherwise is the EPOCH of the RA and DEC measurement used.

PROPER MOTION: The p.m.s are in RA and DEC, with units milli-arcsec per year, in equinox J2000.

MAGNITUDES & COLORS: MAG and COLOR1 are the magnitude and color used to calculate MAG_ACA, using formulae described elsewhere in this document. If no color data are available, we assume $(B-V) = 0.7$, which is close to the data and model mean values for a variety of Galactic positions and $V < 13$ in Bahcall & Soneira (1984, ApJS, 55, 67). When color data exists, we choose a color closest to $(B-V)$ when possible, since conversion errors from other color systems are generally large. Otherwise, a published color will be translated into $(B-V)$ for use in converting MAG into MAG_ACA. In the case of the PPM, a spectral type is converted to a $(B-V)$ color and listed in COLOR1.

ERRORS for MAGNITUDE & COLOR: If a spectral subtype is given, we assume a color error of $\pm$0.2mag if $(B-V) \leq 1.3$, and $\pm$1.2mag if $(B-V) > 1.3$ (see below). Without a spectral subtype, we simply assume $\pm$1.5mag color error. This assumption is conservative for the $\geq 90\%$ of stars with $V < 19$ have $(B-V) < 1.3$. All these errors reflect that no reddening is yet included when converting from spectral type to color.

In order to compute colors from the HD/MK spectral types, Galactic extinction is best accounted for as in Arenou et al (1992 A&A, 258, 104). Using their predicted reddening, and the MK/HD spectral types, they find errors in the computed colors of $(B-V)$ of $\sigma_{MK} = 0.09$mag, and $\sigma_{HD} = 0.17$mag. If the reddening correction is ignored, and the ratio of MK to HD variance is the same, they find $\sigma_{MK} = 0.15$mag, and $\sigma_{HD} = 0.29$mag. This last number is appropriate to the AGASC, since our spectral types come from the PPM (=HD) catalog and we are so far ignoring reddening.

The conversion of m_{ACA} depends critically on spectral type, but can be crudely approximated as linear in two ranges

$$m_{ACA} - V = -0.6(B-V); \quad \text{for} \quad B-V < 1.3$$
$$m_{ACA} - V = -4(B-V) + 4; \quad \text{for} \quad B-V > 1.3$$

Given the error $\sigma_{HD} = 0.29$mag for the HD stars above, we find a color-error term in the predicted m_{ACA} of $\pm$0.2mag if $(B-V) \leq 1.3$, and $\pm$1.2mag if $(B-V) > 1.3$. Given typical 1σ errors in the GSC of ~ 0.3mag, we derive errors for m_{ACA} of $\pm$0.4 mag for $(B-V) \leq 1.3$, and $\pm$1.3mag if $(B-V) > 1.3$.

COLOR2 and COLOR2_ERR are kept at –9999 until further color information is available.

MAG_BAND: (bandpass for mag) These are taken directly from the HST GSC1.1 (see § 6), except for PPM V mags (MAG_BAND=21) and PPM B mags (MAG_BAND=22).

CLASS: (classification codes; first 5 from GSC1.1)

```
0 - star
1 - galaxy
2 - blend or member of incorrectly resolved blend.
3 - non-star
5 - potential artifact
6 - Known multiple system (ala Hipparcos)
```

(1 is rare, and hand-entered; galaxies successfully processed by the software have a classification of 3. Code 4 is unused.)

VAR: (variability codes following Hipparcos; none yet included) VAR is set at -9999 and VAR_CATID is set to 0 for now, since neither PPM or GSC1.1 include variability information.

ASPQ1: (aspect/guide star quality codes)

Aspect star quality codes are defined by a search within 20arcsec of every AGASC star to determine potential spoiler stars:

1) the distance between the two stars computed as:

$$r = \sqrt{((ra1 - ra2) * cos(dec))^2 + (dec1 - dec2)^2} - err$$

$$err = \sqrt{poserr1^2 + poserr2^2}$$

in the appropriate units.

Some stars with poserr$> 32.767''$, show POS_ERR=-9999, to be recognized as garbage.

The exact formula for the angular distance between objects

$$r = acos[cos(dec1) * cos(dec2) * cos(ra1 - ra2) + sin(dec1) * sin(dec2)]$$

must be used when the declination is greater than 89degrees. There, the approximate quadratic relation breaks down. This represents about 1,000 stars in the HST GSC.

2) the mag difference between the two stars computed as:

$$magerrtot = \sqrt{errm1 * errm1 + errm2 * errm2}$$

$$dM = (m2 - m1) - magerrtot$$

(Here m1 is the ACA mag for the 'central' star being checked, and m2 is the ACA mag for a nearby star that might be a spoiler. Mags are in mags. Here errm1 and errm2 are the errors in the ACA mags, also in units of mags.)

```
ASPQ1      RADIUS(")       dM
-----------------------------------
0       none with r<20"
1       15 < r <= 20       dM >=4
2       15 < r <= 20    1< dM <4
3            r <=5         dM >=4
4        5 < r <= 15       dM >=4
5            r <=5      1< dM <4
6        5 < r <=15     1< dM <4
7            r <=20        dM <=1       or multiple stars,
                                       all with dM <4
```

ASPQ2: (high proper motion flag) This flag is 0 for stars with no known p.m. or pm<0.5 arcsec/yr, and 1 for stars with pm>=0.5 arcsec/yr.

ASPQ3: This quality code is for cases where there is one or more spoilers within r< 378" that have very poor positions (POS_ERR=-9999) or (for the future) are very extended objects

```
ASPQ3      RADIUS          deltaM
-----------------------------------
0       none with r<=378"
1            r <=378"       4mag >= dM >=1mag
2            r <=378"       dM <1mag
3            r <=378"       multiple, counting only dM <=4mag
```

ACQQX: (acquisition star codes) The ACQQ spoiler codes are a function of slew angle. Six ACQQX quality codes are assigned for each of X=1 through X=6 slew ranges. These ranges are set to 0-30, 30-60 60-90, 90-120, 120-150, and 150-180. For each ACQQX, the magnitude difference of the brightest star in a circle that is within a radius of the central star of

$$rX = 2\sqrt{2 \times (X/6) \times 133''} = 62.7 \times X\text{arcsec}$$

is cataloged. Thus the circles corresponding to ACQQ1 through ACQ6 are

codeX	r <= rX
ACQQ1	62.7
ACQQ2	125.4
ACQQ3	188.1
ACQQ4	250.8
ACQQ5	313.5
ACQQ6	376.2

The quality code ACQQx is not really a code, but is the difference

code= $100 \times [(m2 - m1) - magerrtot]$

between m2, the ACA mag of brightest star in the circle of radius=rX and m1, the ACA mag of the central star in consideration. The result is thus in 0.01mag units.

5 SUMMARY of CONSTITUENT CATALOGS

5.1 The Hubble Space Telescope Guide Star Catalog (GSC)

The HST Guide Star Catalog (GSC), constructed to support the operational need of the Hubble Space Telescope for off-axis guide stars, contains 18,819,291 objects in the seventh to sixteenth magnitude range, of which more than 15 million are classified as stars. The GSC is primarily based on an all-sky, single epoch, single passband collection of Schmidt plates. For centers at +6 degrees and north, a 1982 epoch "Quick V" survey was obtained by the Palomar Observatory, while for southern fields, materials from the UK SERC J survey (epoch approximately 1975) and its equatorial extension (epoch approximately 1982) were used.

Photometry is available in the natural systems defined by the individual plates in the GSC collection (generally J or V), and the calibrations are done using B, V standards from the Guide Star Photometric Catalog. The overall quality of the photometry near the standard stars is estimated from the fits and other tests to be 0.15 mag (one sigma, averaged over all plates), while the quality far from the sequences is estimated from the all-sky plate-to-plate agreement and from comparisons with independent photometric surveys to be about 0.30 mag (one sigma), with about 10% of the errors being greater than 0.50 mag.

Astrometry, at equinox J2000, is available at the epochs of the individual plates used in the GSC; and the reductions to the reference catalogs (AGK3, SAOC, or CPC, depending on the declination zone) use third order expansions of the modeled plate and telescope effects. Estimates of the overall external astrometric error, produced by comparisons of

independently measured positions without regard to location on the GSC plates, are in the range 0.4 arc-sec to 0.6 arc-sec.

Further details concerning the HST GSC can be found in the following publications:

1. The Guide Star Catalog. I. Astronomical and Algorithmic Foundations; Barry M. Lasker, Conrad R. Sturch, Brian J. McLean, Jane L. Russell, Helmut Jenkner, and Michael M. Shara; Astrophysical J. Suppl., 68, 1-90 (1988).

2. The Guide Star Catalog. II. Photometric and Astrometric Calibrations; Jane L. Russell, Barry M. Lasker, Brian J. McLean, Conrad R. Sturch, and Helmut Jenkner; Astronomical J., 99, 2059-2081 (1990).

3. The Guide Star Catalog. III. Production, Database Organization, and Population Statistics; Helmut Jenkner, Barry M. Lasker, Conrad R. Sturch, Brian J. McLean, Michael M. Shara, and Jane L. Russell; Astronomical, J., 99, 2081-2154 (1990).

4. The table rev_1_1.tbl that accompanies the HST GSC1.1, as prepared by the Space Telescope Science Institute (ST ScI), 3700 San Martin Drive, Baltimore, MD 21218, USA. GSC 1.1 analysis and production were performed primarily by Jesse B. Doggett, Daniel Egret, Brian J. McLean, and Conrad Sturch.

5.2 The Positions and Proper Motions (PPM) Catalog

PPM North gives J2000 positions and proper motions of 181731 stars north of -2.5 degrees declination. The mean epoch is near 1931. The average mean errors of the positions and proper motions are 0.27" and 0.43"/cen. On the average six measured positions are available per star. In addition to the positions and proper motions, the PPM (North) contains the magnitude, the spectral type, the number of positions included, the mean error of each component of the position and proper motion, and the weighted mean epoch in each coordinate.

PPM South gives positions and proper motions of 197179 stars south of about -2.5 degrees declination. This net is designed to represent as closely as possible the new IAU (1976) coordinate system on the sky, as defined by the FK5 star catalogue (Fricke et al., 1988).

Further details concerning the PPM catalogs can be found in the following publications:

1. Catalogue of Positions and Proper Motions; Roeser S., & Bastian U., 1988, Astron. Astrophys. Suppl. 74, 449

2. PPM South: A reference star catalogue for the southern hemisphere; Bastian, U., Roeser, S., Nesterov, V. V., Polozhentsev, D. D., Potter, Kh. I., 1991, Astron. Astrophys. Suppl. 87, 159

6 MATCHING and MERGING

We first performed a simple positional matching of the HST GSC1.1 to the PPM catalog. The latter provides magnitudes and p.m.s for 326518 stars down to about $V = 12$. The PPM could thus provide an astrometric net adequate at least for initial testing of the SSA. A second pass checked positional matches to see that magnitudes in the 2 catalogs were in sufficient agreement. Finally, m_{ACA} was derived for every matched star, and the resulting surface density of stars as a function of magnitude checked against the figure of merit (FOM) of 5.11deg^{-2}. Objects classified as non-stellar, unmatched objects, and objects fainter than $m_{ACA} = 10.2$ are retained in the final merged catalog, again to avoid confusing the SSA with 'spoiler' objects. We included only the subset of the PPM with listed spectral type, consisting of 296637 stars.

Studying a variety of celestial positions, including or excluding non-stellar objects, we find an optimal positional matching tolerance of $\Delta <= 10''$. To that separation, 295871 stars (99.74%) are matched.

To verify positionally matched stars, especially in more crowded regions, we seek to compare magnitudes between the GSC1.1 and PPM. These mags are most often measured in different passbands. For simplicity, and greatest likelihood of compatibility with future merged catalogs, we convert all magnitudes to the V band for comparison. This conversion requires some color information. Using the PPM spectral types, we obtain $(B-V)$ colors by interpolation using the table of $(B-V)$ for each spectral type for main sequence numbers stars from Schmidt-Kaler, Th. Table 4.1 (1982, in Landolt-Bornstein, Springer-Verlag, vol. 2, p. 1, as used by Arenou et al. 1992, AA, 258, 104), and express the conversion to V via a single coefficient α, where

$$m_{GSC} = V + \alpha(B-V)$$

is used when the PPM mag is V (119189 stars), or

$$m_{GSC} = B + (\alpha - 1)(B-V)$$

is used when the PPM mag is photographic (close to B; 177179 stars). A wide variety of bandpasses were used to construct the GSC1.1, for which we have compiled a complete list of α coefficients. By examination of histograms of $m_{GSC} - m_{GSC}^{Calc}$ of positionally matched stars, a magnitude tolerance of 2mag was allowed in the matching. The large tolerance results from a variety of factors including at least a) poor GSC1.1 magnitudes for bright stars, due to a poor mag-diameter relation, halos and/or diffraction spikes b) large color uncertainties since the PPM SpTypes may be crude and include no luminosity class, c) random mag errors

in either catalog.

The total number of PPM stars with some SpType designation retained throughout our matching process is summarized in the table below.

sample	selection	N_{stars}	% of PPM
PPM stars	none	296637	100
GSC1.1:PPM	$\Delta < 10''$	295871	99.74
GSC1.1:PPM	$\delta m <$ 2mag	295274	99.54

After both position and magnitude matching, a histogram of matching failures reveals that essentially all PPM stars have $6 < V < 12$. Very few are brighter than $V = 7.5$. This is because 20,265 GSC 1.0 entries matching INCA stars brighter than $V = 7.5$ (or $B = 8.0$ for those lacking V magnitudes) were replaced in GSC1.1 by INCA data from the HIC (Turon et al. 1992, AAp, 258, 74; Jahreiss et al. 1992, AAp, 258, 82; Grenon et al. 1992, AAp, 258, 88). At the faint end, the number of unmatched PPM stars falls off more strongly than the PPM itself for $V > 10$, presumably because astrometry is best in the GSC1.1 for these fainter stars. The differential histogram of matched stars for all PPM stars with PPM visual mags turns over at $V = 9$, and is only a few hundred stars by $V = 12$ (Figure 6).

7 CALCULATION of INSTRUMENTAL MAGNITUDES

The α factors multiply a $(B-V)$ color, when available, to convert each bandpass magnitude from the GSC1.1 into a V mag for matching to the PPM. When a $(B-V)$ color is not available (e.g., if the SpType is not determined, or not interpolatable from Allen), we adopted the mean $(B-V)$ color of the PPM, $\langle B-V \rangle \approx 0.5$. In cases where the PPM lists only spectral class, but not subclass (e.g., 'O'), we adopt the middle subclass (e.g., 'O5').

The conversion from V to m_{ACA} was determined by convolving the ACA bandpass with the Bruzual-Persson-Gunn-Stryker stellar spectrophotometric atlas. This is an extension of the Gunn-Stryker optical atlas (Gunn, J. E. & Stryker, L. L., 1983 ApJS, 52, 121) where the spectral data have been extended into both the UV and the infrared. The IR data are from Strecker et al. (ApJ 41, 501, 1979) and other unpublished sources (see http://ra.stsci.edu/documents/SyG/SG_1.html). Since the bandpass information for all filters is normalized, the zeropoint for each filter was established by convolution of the bandpass with a mag=0 spectrum of type G0V (BD+26 3780 in the Bruzual-Persson-Gunn-Stryker atlas, normalized to $V = 0$). V and m_{ACA} mags are then derived for each spectral type (SpType), resulting in a $m_{ACA} - V$ as a function of $(B-V)$ color.

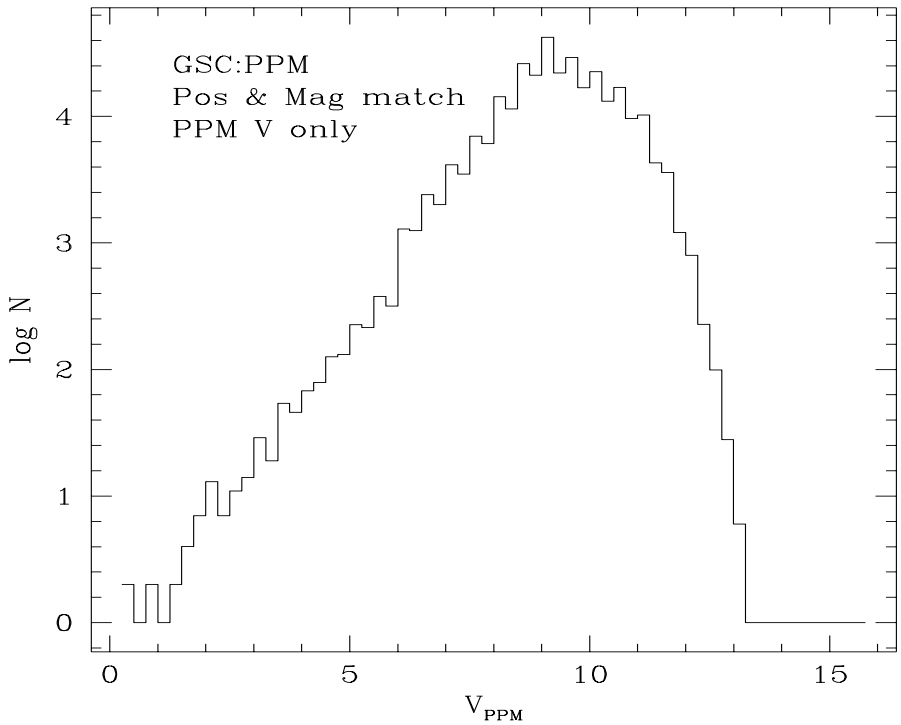


Fig. 6: Histogram of the number of stars matched in both position and magnitude between the GSC1.1 and PPM catalogs, in 0.25 mag bins of 0.25 V. Only stars with PPM V (not *pg*) mags are included.

The relation goes severely non-linear redder than $(B-V)=1.4$. For the range $-0.2 < (B-V) < 1.3$, a good fit is $m_{ACA} = V - 0.577 \pm 0.003(B-V)$, with rms=0.026. The best fit is achieved for the entire color range as follows;

$$\text{MAG_ACA} = V + C_0 + C_1 \times \text{COLOR1} + C_2 \times \text{COLOR1}^2 + C_3 \times \text{COLOR1}^3 + C_4 \times \text{COLOR1}^4$$

where

$$C_0 = 0.283; C_1 = 0.58; C_2 = 0.23; C_3 = 0; C_4 = -0.21$$

(see Figure 7). Similar values were found by Mark Birkinshaw with a more limited stellar library in his memo, 4 August 1994. Those estimates used an A0V zeropoint, and so yielded instead a constant offset near zero. The zero instrument magnitude is now defined as the Aspect Camera response to a zero magnitude star of spectral class G0V (6030 K; see Section 3.2.1.13.1 of the TRW ACA EQ spec EQ7-278D). The estimated value of m_{ACA} is included

in the final merged AGASC for all stars with known SpType from the PPM. For those stars of unknown SpType, we assume $(B-V)=0.7$.

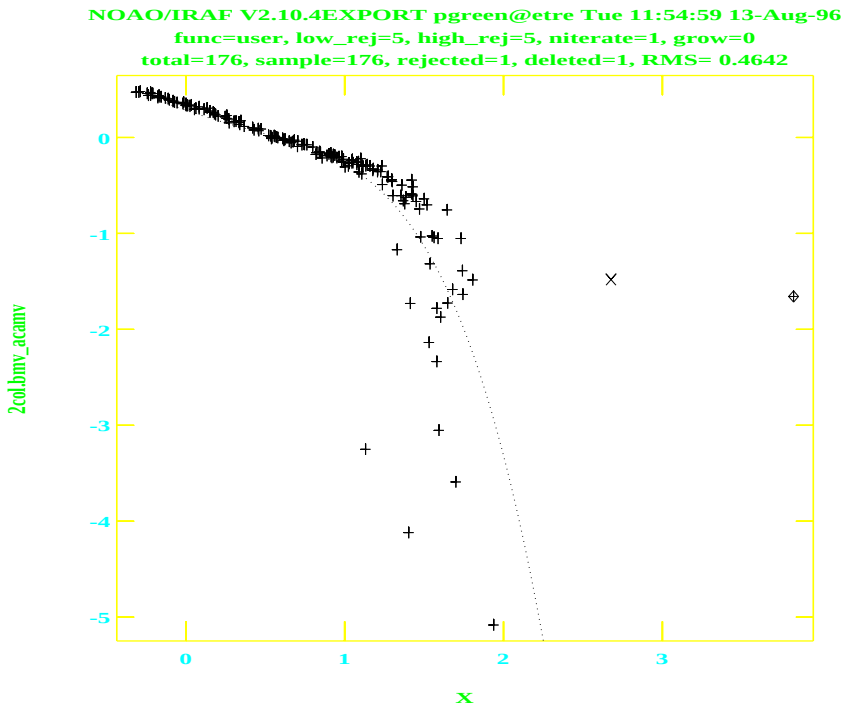


Fig. 7: The abscissa (labeled X) is $(B-V)$ color, and the ordinate is (m_{ACA}-V). A 4th order fit is shown as a dashed line. Colors were derived by convolution of magnitude transmission curves with the Bruzual-Persson-Gunn-Stryker stellar spectrophotometric atlas, using V zeropoints derived from a spectrum of a magnitude zero A0V star, and m_{ACA} zeropoint from a spectrum of a magnitude zero G0V star.

The final error on MAG_ACA is calculated using MAG_ERR and the above conversion:

$$\mathrm{MAG_ACA_ERR}^2 = \mathrm{MAG_ERR}^2 + (\mathrm{COLOR1_ERR}^2) \times$$
$$[C_1 + 2C_2 \times \mathrm{COLOR1} + 3C_3 \times (\mathrm{COLOR1}^2) + 4C_4 \times (\mathrm{COLOR1}^3)]^2$$

8 ERRATA

This is a quick summary of the results of validation and verification (V&V) of the AXAF Guide and Aspect Star Catalog, version 1.1 (AGASC1.1) performed by Paul Green with help from Jon Schachter. THese (relatively minor) problems are presented here for troubleshooting purposes, and will be corrected in the next release.

```
POSITION DIFFERENCES:
---------------------------------
This problem was discovered by the catalog 'designers' after the
developers had already performed the matching: During matching to the
PPM, and spoiler code calculations, the distance between the two stars
was always computed as

    r = sqrt( ((ra1-ra2)*cos(dec))^2 + (dec1-dec2)^2 ) - err

The exact formula for the angular distance between objects

    r = acos[cos(dec1)*cos(dec2)*cos(ra1-ra2) + sin(dec1)*sin(dec2)]

should have been used when the declination is greater than 89degrees.
There, the approximate quadratic relation breaks down.  This
represents about 1,000 stars in the HST GSC.  No need to change this
for AGASC1.1, but it MUST be included in future releases.

ASPECT STAR SPOILER CODES:
---------------------------------
The desired spoiler codes for aspect stars are shown above
in section~\ref{spoilercodes}.  The definition actually used for
ASPQ1=7 in the AGASC1.1 was r <= 20,  dM <= 1 or multiple stars.  All
stars were considered, not just those with dM < 4.  This increases the
number of stars with ASPQ1=7.


ACQUISITION STAR SPOILER CODES:
---------------------------------
Acquisition star codes for each of x=6 slew ranges should
have been assigned via the the formula
```

```
   rX = [1 + sqrt(2)]*(X/6) * 133 arcsec = X*62.7 arcsec

The first factor was incorrectly 2*sqrt(2) for the clear circle in
spoiler/SSA calculations.  This results in an area too large
(conservative) by about 36\%.


INSTRUMENTAL MAGNITUDES MAG_ACA, AND ERRORS MAG_ACA_ERR:
-------------------------------------------------------------------
It appears that MAG_ACA was calculated always assuming default color
(B-V)=0.7, except for those stars whose PPM mags were included
(MAG_CATID=2). This means that all stars using a magnitude from the
GSC (MAG_CATID=1) but colors from (spectral types from) the PPM have
incorrect MAG_ACA values.  As a consequence, spoiler codes for these
stars and for stars near to them are also incorrect.

Similarly, MAG_ACA_ERR was calculated always assuming default color
error COLOR1_ERR=1.5, except for those stars whose PPM mags were
included (MAG_CATID=2).  Thus, MAG_ACA_ERR is incorrect for
these, an error that has few profound implications at the moment.

There appear also to be minor exceptions to this.  1) There
are several stars that have PPM mags, for which the default color
error is still assumed.  Examples are (AGASC_IDs) 17280221 and
13343868. 2) There are stars that do have GSC mags, but PPM colors,
where the correct colors and color errors were used in calculating
MAG_ACA and MAG_ACA_ERR.  These all appear to have CLASS=6.
Examples are 18839542, 18839546, 18840125.


FITS REGIONS MISPLACED
---------------------------------
The files below should be moved from n5230 to n6000.

4014.fit
4015.fit
4016.fit
4017.fit
```

```
ACQQx
-------------------------
Specifications called for ACQQx to be

        code= 100*[(m2 - m1) - magerrtot]

while, it appears that the error was not used.
```

9 STAR COUNTS in AGASC1.1

9.1 Matched Star Counts by ACA Magnitude

The surface density of objects brighter than $m_{ACA} = 10.2$ (G0V zeropoint, after both positional and mag matching) in both the GSC1.1 and PPM catalogs is 10.1deg^{-2} for $|b| < 10°$, and 4.7deg^{-2} at $|b| > 80°$. Thus, matching only PPM stars to the GSC1.1 *does not* achieve the required FOM surface density of 5.11deg^{-2} to an instrumental magnitude of $m_{ACA} = 10.2$.

Bahcall & Soneira (1984) Galactic models suggest a total surface density of 7.6 stars deg^{-2} to $V = 10.5$, even at the NGP. Our failure to reach these densities with only the PPM is mostly due to its rather severe incompleteness for $V > 10$. The required FOM may be reached if other catalogs can be included.

9.2 Achievable Star Counts by ACA Magnitude

To exclude the possibilty of uncatalogued stars with $m_{ACA} < 10.2$ (but cataloged mag > 10.2) confusing the SSA, we should be as complete as possible to the corresponding V mag for the reddest stars. Data and models show that at high Galactic latitudes, $(B - V)$ colors exceed 2 for a negligible fraction of stars having $12 < V < 16$ (B&S), but may reach 1.5mag. Given the (4th order) transformation between V and m_{ACA} (§ 7, with G0V normalization), the reddest stars have $(V - m_{ACA})$=3.3. Including an error budget of 0.7mag in colors and transformations, the AGASC should be as complete as possible, with colors, to $V \approx 14$ This corresponds quite well to the HST GSC1.1, which, however lacks color and proper motion information - the motivation for our catalog merging.

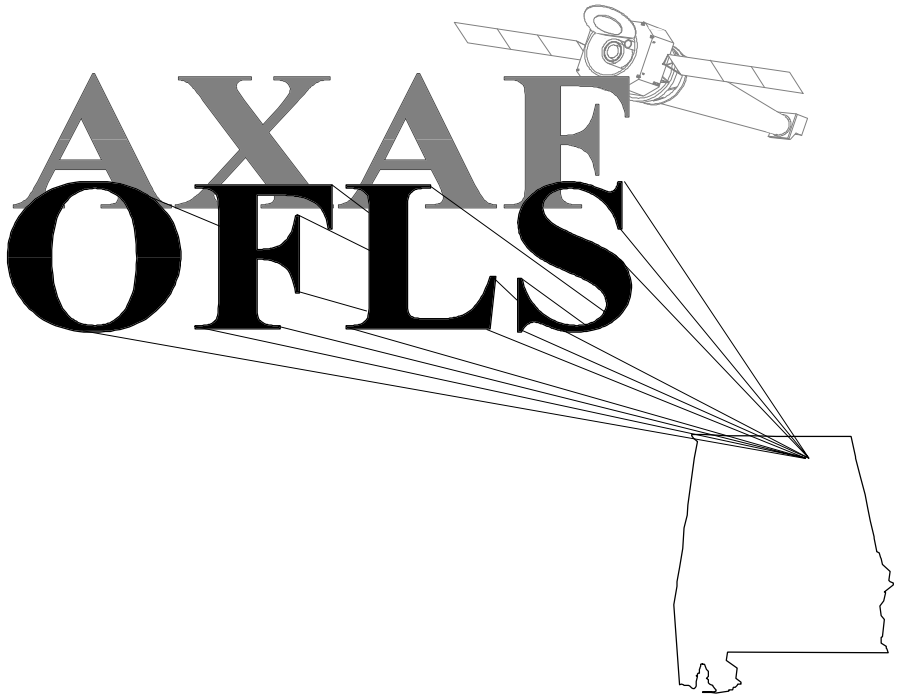
10 FUTURE RELEASES of AGASC

A variety of catalogs are being considered for inclusion to make future versions better satify our requirements.

AGASC1.2: (due 9/97) This version will likely include a merge of the Tycho Output Catalog (TOC) with the HST GSC. The TOC (release date Spring 1997) includes about a million stars 'almost complete' to V=10.5 with typical precision 0.04 mag, colors with $(B-V)$ precision < 0.06 mag, and astrometry with precision < 0.01 arcsec. Tycho stars are already cross-referenced to GSC IDs for easy matching.

AGASC2.0: (due 9/99) This version should include accurate mags, colors and astrometry for all objects down to at least $V = 14.5$. We expect this to include either the scanned POSSII or the Flagstaff USNO survey, both of which are now underway. Details of USNO-A 1.0, which is now available are: About 488 million objects, complete to at least $B \sim 19$, with photometric accuracy < 0.40 mag, and astrometric accuracy < 0.25 arcsec. USNO-A 2.0 (scheduled release October 1997) will tie-in all astrometry to Tycho/Hipparcos system. AGASC2.0 may well be ready before the due date.

The ACA magnitudes listed in future versions of the catalog may also be modified several ways. 1) Based on observed in-flight ACA magnitudes, a more accurate magnitude calculation as a function of (B–V) color can be verified, and if necessary, a recalibration of the whole catalog may be performed. 2) Observed ACA magnitudes will be stored and substituted into a working version of the AGASC, with occasional re-release versions planned.



Star Selection Algorithm Review

M. Newhouse

Computer Sciences Corporation

November 6, 1996

Star Selection Algorithm Review

Memorandum provides complete comments

- **technical concerns**
- **potential impacts for changes to OFLS baseline design**
- **changes accommodated by current design**
- **editorials**

Presentation only covers the first two topics

Concerns (1 of 3)

Non-AGASC stars specified on the OR (section 3.1, page 3) should be used as spoilers for FID, exclusion box, and column filters

Radial spoiler check added to acquisition star processing (section 3.2, page 5) but not defined

Checks on OR (and ER) specified stars (section 4.4.1, page 6) should include the FID light spoiler check

Exclusion box radius filter (section 4.6.4, page 6)

- **use for "nearest neighbor" check (13 pixel restriction)**
- **use commanding flexibility to set search box size to exclude nearby stars**

Concerns (2 of 3)

Acquisition star quality code filter on maneuver length cannot be accommodated as stated in the OFLS design (section 5.6.1, page 18)

- **OFLS determines star availability up front and uses the information during scheduling**
- **maneuver length not available until schedule processing**
- **may be possible to skip filter until schedule has been laid out, use filter for final determination of best acquisition stars**
- **not covered by current OFLS design**

Concerns (3 of 3)

Alignment of CCD coordinates to the AXAF axes for FOM calculation (Appendix C, page 29)

- **primary and backup ACAs rotated 180 degrees with respect to each other**
- **requires separate alignment definitions for each**

Requirement Updates Not Covered By Baseline OFLS Design (1 of 2)

Additional OR parameters

- **specify whether independent acquisition stars must be selected (section 1.2, page 1)**
- **specify whether a star position is to be monitored without being used in the FOM calculation (section 3.1, page 3)**
- **specify minimum number of acquisition stars and guide stars to be selected (section 4.7.1, page 11 and section 5.7, page 19)**
- **Note: we assume all changes to the OR OBS statement should be supported by the ER CAL statement**

Additional calculation of the FOM for OR-supplied stars (section 4.1, page 6)

Requirement Updates Not Covered By Baseline OFLS Design (2 of 2)

Additional filters for candidate acquisition and guide star processing

- **star class (section 4.6.2, page 10; section 5.6.2, page 18)**
- **readout register spoilers (section 4.7.2, page 11; section 5.7.1, page 19)**

Bad pixel map definition

- **prototype software defined as upper left and lower right corner boundaries**
- **current document defines as pixel map reducing processing efficiency**
- **options**
  - **redefine bad pixel map format**
  - **add OFLS preprocessor to determine region corners**

MPSWG, Nov 1996, OP19 Changes, Michael Garcia, ASC

OR Formats:

Additions to OR/STAR: (page 161 of OP19)

id number	AGASC ID#	Int	0->2x10^7	1
Type	star type	ascii	guide/acq/b/mon	-

Add to the star type parameter “mon”, for “monitor”. The search window for the star will then be set with the monitor flag set to on, and the stars window will track the window of the NEAREST other star window. The ‘Convert to track’ flag will be enabled in the same manner as for other guide star, but the ‘threshold’ should be set to ‘mon_conv_to_track_thres’, a new op19 entry with an initial value of 10.2 (see below)

Additions to OR for SSA (page 160-163 OP19)

These are to MATCH entries in the ODE, section 3.2.3.1, and override them if they are set in the OR

min_number_acq_stars	Int	1-8	1
select_acq_from_guide	ascii	yes/no	- (not in 3.2.3.1)

If yes, then attempt to select acq stars from acceptable guide star sets, in order to decrease the size of the star catalog upload to the ACA and to decrease the time required to intitiate Normal Point Mode.

num_guide_stars	Int	1-8	1

ADD to OP19:

mon_conv_to_track_thres	real	8	sao	initial=10.2

description: if a star (or region) is set to be ‘monitored’, then the threshold for ‘convert to track’ is set by this parameter

odb_guide_image_thres	real	8	sao	initial = 3
odb_acq_image_thres	real	8	sao	initial = 3

description: The faint magnitude limit thresholds for acq/guide stars in the MANACQ (3.1.3.2) statement, AGMINX, AGMMINX, should be this

many times below the magnitude error for the stars as read from the AGASC.

The following are changes to the Characteristics section of OP19, 3.2. They have been made in order to rectify OP19 with the SSA Document of Oct 1996. Naming conventions in OP19 should follow the lead of the SSA Document. Page numbers refer to the Sept 6 1996 version of OP19 and the Oct 11 1996 version of the SSA Document.

Page 33 of OP19 -
Under 'initial value provider', change TBD to SAO for

odb_ac_search_rad
odb_ac_min_pix_row
odb_ac_max_pix_row
odb_ac_min_pix_col
odb_ac_max_pix_col
odb_pixel_size

page 34 of OP19: the entire set of entries for the ACA magnitude conversion should be replace with the entries from the SSA Oct 1996. We require a fourth order polynomial in at least one color, this is not supported by the entries in the Sept 6 OP19 (which allows up to second order in three colors).

Page 37 of OP19: odb_ad_bad_pixels - Per request from CSC (M. Newhouse, 11/6/96 MPWG), this will remain a list of corners describing rectangular bad pixel regions.

The following entries should be RENAMED as follows in order to adhere to SSA Oct 1996.

old	new
odb_min_sep_fid	odb_fit_spoil_region
odb_min_rad_mag	odb_rad_mag_diff_limit
odb_min_col_sep	odb_col_spoil_col_limit

Page 38 of OP19:The following entries should be RENAMED as follows in order to adhere to SSA Oct 1996.

old	new
odb_min_col_mag_g	odb_col_mag_diff_limit_gg
odb_min_col_mag_a	odb_col_mag_diff_limit_a
odb_min_exe mag	odb_exc mag_diff_limit

page 39 of OP19: The six entries from:
odb_max_offax_sigma, through
odb_aca_add_array
should be replaced woth 5 arrays and multipliers from page 33 of the SSA Oct 1996. These are 1024x1024 arrays of reals.

Change the name of
odb_min_fom to odb_max_acceptable_fom
this is the maximim (not minimum) acceptable value of the figure of merit for accepting guide stars.

Page 40 of OP19: The following entries should be RENAMED as follows in order to adhere to SSA Oct 1996.

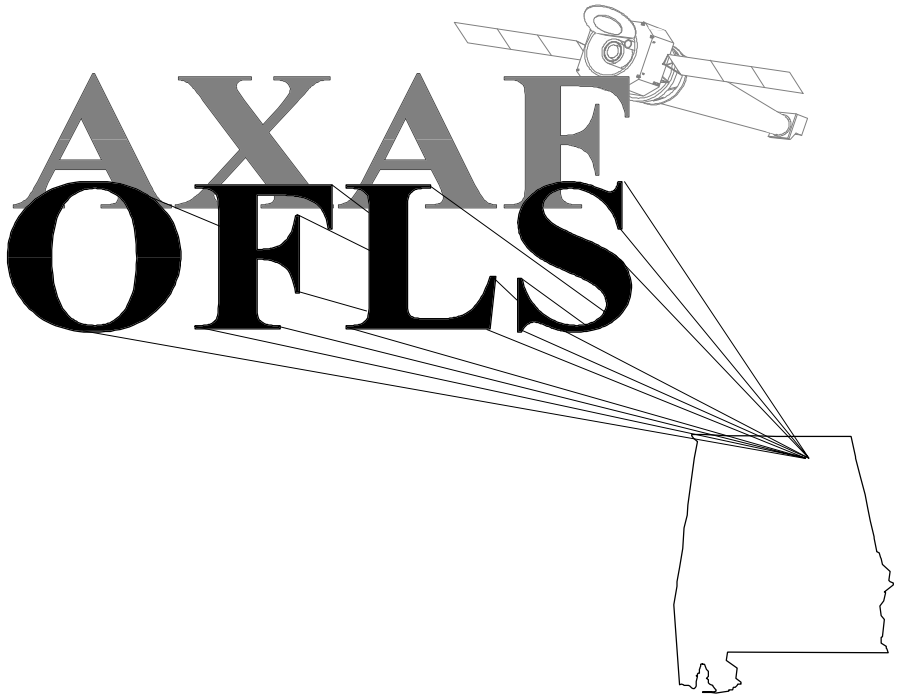
old	new
odb_fit_int_ac	odb_fix_aca_mag
odb_min_acq	odb_min_num_acq_stars
odb_max_ac	odb_num_acq_stars
odb_max_guide	odb_num_guid_stars

The following entries should be removed and replaced with SSA entries:
remove
odb_lasm_as
odb_lasm_st
replace with entries from page 31 of SSA Oct 1996
max_point_error , maximum pointing error during attitude hold (arsec)
max_dither , maximum dither amplitude

page 41 of OP19: the format, comment, and length need to be changed for:

odb_min_cl_a
this is a REAL number, 8 bytes long, defining the minimum allowable value to the APPROPRIATE quality code for acq stars. The appropriate quality code depends on the length of the slew to the target, as described in the SSA.

the five entries from
odb_max_cl a, through
odb_max_c3 a
should be replaced with the entries from page 34 of the SSA



OP-19 Updates

M. Newhouse

Computer Sciences Corporation

November 6, 1996

OR/ER Updates

All statements

- **add OVERLAP parameter**
  - **support orbital activation and checkout (OAC) scheduling**
  - **specify requests which must be scheduled concurrently**
- **clean-up specification of required parameters and subparameters and default values for optional parameters**

OR/ER Updates

OBS and CAL statements

- **add target name as an optional subparameter to the TARGET parameter: TARGET(ra, dec, name)**
- **add reference frame (spacecraft or GCI) as an optional subparameter to the MANEUVER parameter: MANEUVER(v1, v2, v3, angle, ref)**

CAL statement

- **add ESA, FSS as allowable instruments**
- **add Sun as an allowable target when FSS is specified as the instrument**

COMM statement

- **add RATE parameter to support OAC planning**
- **specifies required rate for requested DSN contact**

Activity Description Updates

Break MANACQ statement into separate statements to support changes to spacecraft commands

- **MANVR statement controls commanding for spacecraft maneuvers to new attitude**
- **ACQ statement controls commanding for onboard processing for guide and acquisition stars**

Scheduled OR/ER Updates

All records

- **add record type indicator**
- **change all values to ASCII**

Header record

- **add the id of the previous schedule using to establish the spacecraft configuration at the start of the current schedule**
- **change units for statistics (time fractions) from relative time to seconds**

Scheduled OR/ER data record

- **expand object start angles, stop angles, closest approach angles, and closes approach times to include**
  - **Sun, Moon, Earth**
  - **all x-ray constraint objects**

Science pointing scenarios

Tom Aldcroft, SAO, 06-Nov-96

Overview

Science pointing scenarios: use full capability of PCAD hardware and on-board software to maximize science return

- Normal pointed observation
- Mosaic large area survey
- Pseudo-track
- Offset and hold
- Slew survey

- **Normal pointed observation** - With or without dither
- **Mosaic large area survey -** images of large regions, e.g. Andromeda galaxy

  - Command multiple observations, nothing special
- **Pseud-track** - Use PCAD "nudges" to perform a sequence of small maneuvers in NPM

  - Track fast moving solar system objects, or perform shallow large area scans

  - PCAD capability: Can stay in NPM if scan speed < 3 arcsec/sec, with attitude error <3 arcsec. Post-facto attitude uncertainty is unknown at this time.

—OBC capability: TRW OP03b documents SCS's that allow pseudotrack

— OFLS capability: Pseudo-track can be accomplished via an activity sequence

— ASC capability: Such an observation requires special processing to pick stars

- 3 arcsec/sec = 72 deg/day
  Moon: 12 deg/day=0.5 arcsec/sec (384,000 km distance)
  NEA: < 1 deg/day Comets: Hyakutake moved at a peak rate of 18 deg/day, at a closest distance of 0.1 au (15x10^6 km)

- There is no need f0r a slew mode *faster* than this:
  ACIS FOV = 16 armin -> 320 sec exposure
  HRC FOV = 32 arcmin -> 640 sec exposure

— 10 degree scan requires ~40-50 stars and 120 target quaternion updates

• **Offset and hold** - If a field has no usable guide stars

—e.g. the Moon

• **"Classic" Slew-survey** - While slewing between objects, SIs can still be taking data. Is there bookkeeping that OFLS needs to do?